Introduction

The 2003 VLAP Sampling Season

The Volunteer Lake Assessment Program (VLAP) set a new volunteer participation record again this season! A total of 153 lakes and 166 lake deep spot stations were tested by volunteers throughout the state. In addition, approximately 450 volunteer monitors participated in the program!

DES would like to extend a special welcome to those volunteer monitoring groups that joined VLAP for the first time this year; these volunteers represent the following waterbodies: Back Lake in Pittsburgh, Baptist Pond in Springfield, Berry Bay in Ossipee, Lower Danforth Pond in Freedom, Little Goose Pond in Canaan, Lake Katherine in Piermont, Kilton Pond in Grafton, Lake Ossipee in Ossipee, Pillsbury Lake in Webster, Rainbow Lake in Derry, and Waukeena Lake in Danbury. And, we welcome back our friends and new monitors at Pequawket Pond in Conway, Shellcamp Pond in Gilmanton, Suncook Ponds in Barnstead, and Wilson Pond in Swanzey, who rejoined VLAP during the 2003 season.

The 2003 VLAP sampling season was another successful year in which "quality" and "representative" data was collected at lakes and ponds throughout the state. This was the second year that the coordinators of the program and the volunteer monitors followed the VLAP Quality Assurance Project Plan (QAPP). The VLAP QAPP is a document that details the procedures that volunteer monitors and DES staff follow in the field collecting samples and also the procedures that DES laboratory staff and VLAP satellite laboratory staff follow while analyzing samples in the laboratory. The QAPP serves not only to convince skeptical data users about the quality of the VLAP's findings, but also to record methods, goals, and program implementation steps for current and future volunteers and for those who may wish to use the project's data over time.

In accordance with the QAPP, many new quality assurance and quality control procedures were implemented during the 2002 sampling season. These procedures included using the *sample receipt checklist* in the laboratory and conducting the *sampling procedures assessment audit* during the annual biologist visit. During the 2003 sampling season, the laboratory staff at DES and the satellite laboratory at Colby Sawyer College continued to implement these quality assurance and quality control procedures. Specifically, the sample receipt checklist was used to check in samples dropped off at the laboratory to determine if the volunteer monitors had followed proper sample collection procedures while sampling on their own. And, during the annual visit to your lake/ pond, the biologist may have conducted a sampling procedures assessment audit to document the ability of your monitoring group to follow the proper field sampling procedures.

Overall, the sample receipt checklists and the annual assessment audits completed during the 2003 sampling season proved that the majority of the monitoring groups follow the proper sampling techniques while collecting lake and tributary samples! Keep up the good work!

Using the QAPP as a guide during future sampling seasons, the coordinators of VLAP will continue to ensure that volunteer monitors and lake associations receive "quality" and "representative" data that can be used to guide educational, lake management, and watershed planning activities. In addition, the data that DES biologists and volunteer monitors gather through VLAP will continue to be used by DES to assess the quality of New Hampshire's lakes and ponds.

Program Updates

As some of you are aware, the Franklin Pierce College (FPC) satellite VLAP laboratory was not able to analyze samples during the 2003 sampling season. This was largely due to personnel and budget issues at the college.

The coordinators of VLAP realize that volunteer monitors in the southwest region of the state rely on the FPC satellite laboratory to borrow equipment and sample bottles and to drop-off samples for analysis. Although the FPC laboratory was not able to analyze samples during the 2003 sampling season, staff at FPC graciously agreed to continue to lend out sampling equipment to volunteer monitors! To make this work, volunteer monitors contacted DES to arrange pick-up of sampling equipment from FPC, DES provided sampling bottles and contacted FPC to put the equipment in the lock box, volunteer monitors picked up and returned equipment to the FPC lock box as scheduled, and then volunteer monitors transported samples to the DES Limnology Center in Concord for analysis. This was truly a cooperative effort and we thank the volunteer monitors in this region of the state for bearing with us this season! And, we would like to extend a special thanks to Fred Rogers and Sue Rolke at FPC for their continued support of VLAP. Furthermore, we want to assure volunteer monitors in this region that DES and FPC are working together to get the FPC lab up and running for the 2004 sampling season.

As usual, we want to assure all volunteer monitors that we are continuing to try to make your job as a volunteer monitor easier. We are currently exploring additional locations to establish satellite laboratories throughout the state. In addition, we are investigating the feasibility of using bus companies to transfer equipment and samples from distant lakes and ponds to Concord. We will keep you updated about these possibilities as the 2004 sampling season approaches!

2003 Weather Conditions in New Hampshire

The weather pattern during the Summers of 2001 and 2002 was relatively straightforward: it was warm and dry, and drought-like conditions prevailed throughout much of the state. The combination of these factors resulted in relatively warm surface waters and the flushing rate of many of lakes and ponds throughout the state was slowed.

However, the weather pattern during the Summer of 2003 was not consistent (i.e.; a mixed bag!), making it difficult to generalize the affect that the weather may have had on the surface water quality throughout the state. Following is a brief, generalized summary of the weather that we observed in the state:

> The Winter of 2002-2003 was very cold and snowstorms of various intensities were frequent. As a result, spring runoff entering lakes and ponds was high in conductivity (primarily due to the use of road salt during the winter) and in phosphorus. The air temperature in May and early June was generally cool and rain storms were common, which resulted in cool surface water temperatures and inevitable nutrient loading to surface waters. During the third week in June, the air temperature quickly became unseasonably warm and the rainy conditions which prevailed earlier in the month subsided to sunny, hazy days with scattered thunderstorms. The weather during the first week in July was hot and dry, and, by mid-July, surface water temperatures in lakes and ponds throughout the state were at their maximum. The third and fourth weeks of July were seasonably warm and relatively dry. The first three weeks of August were rainy and thunderstorms were common, and surface waters began to cool. The last week in August was dry and seasonably warm. The first, third, and fourth weeks in September were rainy and air temperatures, as well as surface water temperatures, continued to cool.

The 2003 VLAP Report

In order to ensure that VLAP continues to provide a “quality” and “timely service” to those who use VLAP data (particularly the volunteer monitors), starting with the 2002 sampling season, the annual report format for VLAP was changed. Specifically, a system of generating a “Biennial Report” or an “Interim Report” on an alternating annual basis for each lake/pond participating in VLAP was implemented.

As explained in the 2002 annual report, the “Biennial Report” and “Interim Report” are quite similar to the “Annual Report” prior to 2002, except for a few minor changes and additions, as shown in the following summary:

Biennial Report Sections	Interim Report Sections
• Introduction	• Introduction
• How to Interpret Graphs and Tables	• How to Interpret Graphs and Tables
• Interpreting Data	• Interpreting Data
• Monitoring Parameters	• Monitoring Parameters
• Observations & Recommendations (full version)*	• Observations & Recommendations (abbreviated)*
• List of Useful Resources	• List of Useful Resources
• Data Quality Assessment & Quality Control	• Data Quality Assessment & Quality Control
• Regression Statistical Analysis**	• No Regression Statistical Analysis**
• Deep Spot Graphs (Chl-a, Secchi-Disk, TP)	• Deep Spot Graphs (Chl-a, Secchi-Disk, TP)
• Data Tables (all sampling parameters for all sites)	• Data Tables (all sampling parameters for all sites)
• Lake Map (showing sampling locations)	• Lake Map (showing sampling stations)
• Special Lake Ecology Related Topic	• Special Lake Ecology Related Topic
• Statistical Analysis** Raw Data & Explanation	• No Statistical Analysis Raw Data**

* = The "full version" of the Observations and Recommendations section will include an in-depth discussion of how the data for each lake/pond specifically relates to the sampling season, historic sampling seasons, and the state mean/median for each parameter, while the "abbreviated version" will discuss each parameter in general.

** = The statistical regression analysis will be conducted for all lakes/ponds that have at least 10 consecutive years of data in order to objectively determine if lake quality has changed over time.

The lakes/ponds monitored through VLAP have been divided into two approximately even numbered groups (alphabetically) and the report schedule has been determined, as shown below:

At the end of Season 2002:

50% of lake/ponds ("A" – "M") received a "Biennial Report"
50% of lakes/ponds ("N" – "Z") received an "Interim Report"

At the end of Season 2003:

50% of lake/ponds ("A" – M") will receive an "Interim Report"
50% of lakes/ponds ("N" – "Z") will receive a "Biennial Report"

(Note: All new lakes/ponds will receive a complete "Biennial Report" after the first season they participate in the program, and an "Interim Report" will be issued after the second season.)

Since it is not realistic to discern changes in lake trend analyses over a short period of time, we are confident that this reporting method will be sufficient for identifying lake quality trends.

Concluding Remarks

We realize that there is a lot of information to digest in the following pages, but we hope the "How to Interpret Graphs and Tables", "Interpreting Data", and "Monitoring Parameters" sections of this report will help you understand the results.

Please read the "Observations and Recommendations" and "Data Quality Assessment & Quality Control" sections of your report carefully, and pay special attention to suggestions that we have made to improve your current sampling program.

In Appendix C, you will find a copy of your lake map. *Please check your map carefully to confirm the location of each sampling station.* Please revise your map as necessary and send a copy of the corrected map to the VLAP Coordinator. DES is currently developing a permanent record of the location of each VLAP sampling station. The location of each VLAP sampling station is being incorporated into the DES water quality database and Geographical Information Systems (GIS) database. Eventually, through the DES GIS website, you will be able to click on a map of your lake/pond and the water quality data for each station will be available!

In Appendix D you will find this year's Special Topic Article, "Septic Systems and Lake Quality: Are Septic Systems a Problem in Your Watershed?" Many volunteer monitoring groups are concerned about the impact of septic systems on lake quality. This article discusses how septic systems should be maintained, how to determine if a system is in failure, and what technologies are available to replace septic systems. In addition, this article will teach you how to conduct a septic system survey in your watershed!

If you have any quesitons about your 2003 report, feel free to contact the VLAP Coordinator. In addition, please contact the VLAP coordinator soon to schedule the annual biologist visit to your lake/pond.

See you soon!

Sincerely,

Andrea LaMoreaux
VLAP Coordinator
Tel: (603) 271-2658
Email: alamoreaux@des.state.nh.us

Jody Connor
Limnology Center Director
Tel: (603) 271-3414
Email: jconnor@des.state.nh.us

P.S. Keep your eye on your mailbox for the 2004 edition of *The Sampler*, the annual VLAP newsletter. In this newsletter, we will announce the 2003 VLAP awards for particularly dedicated volunteer monitors. At the Annual VLAP Workshop, which will be held in May 2004, these volunteer monitors will receive their awards.

How to Interpret Graphs and Tables

Graphs

Observation: a sample or data point

There are two types of graphs in Appendix A of this report, a line graph and bar graph. Each graph conveys much more to the reader than a table or verbal description, so it is important to be able to interpret it correctly. It must be stressed that a lower number of **observations** causes a corresponding decline in the reliability of the information (the more data the better!).

Line Graph

Mean: average. To calculate the mean, the reading or concentration for a particular parameter on each sampling event is added together, which results in a total for the season. The season total is then divided by the number of sampling events during the season, which results in an average concentration or reading per sample event.

The line graph summarizes sampling results for the years you have collected data (see sample line graph below). The graph shows the **mean** for a given year as an up-turned or down-turned triangle. The triangle points in the direction of more desirable values. For example, chlorophyll-a and total phosphorus have downward triangles, indicating lower values are better, while transparency has upward triangles, signifying higher values are more desirable.

Line Graph Depicting Historical Data

Standard deviation: a statistic measuring the spread of the data around the mean

Range: difference between the high and low values

A measure of the spread of the data around the mean, or **standard deviation**, is shown as the vertical lines extending up and down from the mean. Standard deviation is similar to **range** except standard deviation is a more exact measure of variation. In this case, the lines indicating standard deviation on your graphs illustrate the amount of variation in the results for a particular test for all the times you sampled in that year. For example, if all the chlorophyll readings came back with similar results each time you sampled this year, then the amount of deviation from the average is small. If there was a wide range of chlorophyll concentrations in the lake, then the deviation is large.

Regression Line: a statistical tool used to predict trends in data

Trends in the yearly data can be discerned by looking at the **regression line** and noting its direction and degree of slant (see example next page). If the line is slanted downward like this “\”, it indicates an improving trend in chlorophyll-a and total phosphorus but a declining trend in transparency values. If the line is sloped the opposite way (like this “/”), it depicts a worsening trend in chlorophyll-a and phosphorus, but an improving trend in transparency values. The steeper the regression line's slope the stronger the trend. A horizontal regression line indicates the parameter presented is stable, neither improving nor worsening over time.

Caution is warranted when drawing absolute conclusions from annual data if the lake data set is small. Don't panic if the line graph shows a parameter worsening — check your raw data first. Look for years with one extremely high or low sampling point; this could **skew** the trend line. Remember, you need many years of data before trends become apparent, and ten years before they are considered statistically significant. After your lake or pond has been monitored through NHVLAP for at least 10 years, we will analyze the in-lake data with a simple statistical test. Specifically, we will use a linear regression line and regression statistics to determine if there has been an increase or decrease of the annual mean for chlorophyll-a, Secchi-disk transparency, and total phosphorus in your lake/pond since monitoring began.

Skew:a measurment of consistency, or more precisely, the lack of consistency

The last element in the line graph is a line representing the **New Hampshire mean** for that particular parameter . Your data can be compared to this value. For a complete summary of water quality test averages in New Hampshire, please turn to page 10.

NH Mean: data collected from approximately 800 lakes in the state for the NH Lake Survey Program

Bar Graph

The second type of graph found in this report is the bar graph. It represents this year's monthly data for a given parameter. When more than one sampling event occurred in a month, the plotted value will represent **only one result**. Please check your raw data reports to find all of the results. The bar graph emphasizes individual values for comparison rather than overall trends and allows easy data comparisons within one sampling season.

Tables

Tables in Appendix B summarize data collected during 2001 and previous years. Maximum, minimum, and mean values are given for each station by sampling year for most tests, where applicable.

Bathymetry: the topography of the lake's bottom; contours depict lake depths

Lake Maps

Maps in Appendix C show the **bathymetry** of your lake. The "X" denotes the deepest spot in your lake, where most of the in-lake sampling is done. Tributary names for major inlets and outlets are labelled on the map, and should be referred to when labelling sample bottles and studying the data in Appendix B. If the map of your lake is not complete, please make any necessary changes and return the map to us so we can create a new map for your use.

Interpreting Data

Watershed: land draining to a particular water body; often described as a funnel

Fertility: capacity to sustain plant growth

Biological Production: total amount or weight of living plants and animals

Limiting nutrient: nutrient that in small increases can cause larger changes in biological production

Oligo: little

Trophic: food

Oligotrophic: low biological production and nutrients; highest lake classification

Eutrophic: high biological production, nutrient rich; lowest lake classification

Impervious: impenetrable

Epilimnetic: upper water layer

Hypolimnetic: lower water layer

Like all of us, lakes age over time. Lake aging is the natural process by which a lake fills in over geologic time. They fill in with erosional materials carried in by the tributary streams, with materials deposited directly through the air, and with materials produced in the lake itself. From the time that a lake is created, the aging or filling in process begins. Although many New Hampshire lakes have the same chronological age, they change and fill at different rates because of differences in runoff and **watershed** characteristics. Lakes can fill in more quickly than natural due to human impacts. Eutrophication (or lake "aging") is the process of increased nutrient input to a lake exceeding the natural supply. The **fertility** of the watershed, which is dependent upon land use and geology, determines the rate of lake aging. Increased lake fertilization results in an increase in **biological production**.

The key chemical in the eutrophication process is the nutrient phosphorus. Phosphorus is the **limiting nutrient** in New Hampshire lakes; the greater the phosphorus concentration in a lake, the greater the biological production. Biological production can be measured in terms of plant growth, algal growth, decreased transparency, and an overall decrease in lake quality.

It is very important to understand the meaning of biological production when referring to lakes. We often think of biological production as something good. For example, a productive garden yields an abundance of vegetables. But, when speaking about lake productivity, usually the low biological production associated with a clear, **oligotrophic** lake is the ideal condition. Fisherman, on the other hand, may prefer a productive lake, especially if they are fishing for warm water species, like bass. Warm water species thrive in productive lakes because of the abundance of food and presence of plants used for protection and spawning. Excessive plant growth and algae blooms are present in a *highly* productive, **eutrophic** lake.

When eutrophication is caused by human activity it is termed **cultural eutrophication**. This accelerated aging results from watershed activities such as fertilizing, converting forest or pasture to cropland, and creating **impervious** areas such as rooftops, parking lots, and driveways. Studies in New Hampshire have shown that phosphorus exports from agricultural lands is at least 5 times greater than from forested lands, and in urban areas may be more than 10 times greater. Other contributers to cultural eutrophication include faulty septic systems, bathing in or near the lake, sediment erosion into the lake, dumping or burning leaves and trees in or near a lake, and feeding ducks.

As you interpret the data on the following pages, pay close attention to the trends. Look for increases or decreases in the **epilimnetic** and **hypolimnetic** phosphorus. If you observe an increase in hypolimnetic phosphorus as the summer progresses, a process called *internal phosphorus loading* is occurring. This means phosphorus that was tied up in the lake floor sediments is now able to enter the water column. **Anoxia** initiates this process.

What if there was an increase in epilimnetic phosphorus? As you look at the data from the inlets, notice if this year's data show an increase in phosphorus from a particular inlet. If the increase is signficant the new source of phosphorus should be investigated. Investigations may include a watershed walk or bracketing the brook for further sampling.

Transparency: water clarity

Chlorophyll-a: green pigment found in plants; used to measure the amount of algae in a lake

Correlations between **transparency** and **chlorophyll-a** are important. If the chlorophyll-a increased and the Secchi disk transparency decreased increased algae populations are affecting the water clarity. If the chlorophyll-a has not increased, but the transparency has undergone a decline (for example, a reading from 4 meters down to 2 meters) the reduced transparency could be attributed to turbidity caused by stream inputs, motorboat activity, shoreline construction, or disturbances of bottom sediments. In shallow lakes, less than 15 feet in depth, the wind can produce wave action that can disturb the bottom sediment creating high turbidity.

Non-point pollution: pollution originating in the watershed, often entering the water body via surface runoff or groundwater

Conductivity, acid neutralizing capacity (ANC), and pH should also be examined. The lower the ANC value for your lake the more vulnerable it is to acid precipitation. Conductivity is a good indicator of disturbance or **non-point sources** of pollution. A marked increase or decrease in any parameter should be investigated.

Epilimnion: upper water layer

Metalimnion: middle water layer (a.k.a. thermocline)

Hypolimnion: bottom water layer

All of the data might seem overwhelming to you at the start. First, take a look at the in-lake data. The tables in Appendix B will list in-lake data either as **Epilimnion, Metalimnion,** or **Hypolimnion.** The number of layers formed in a given year is dependent upon lake depth and seasonal temperatures; if your lake has two layers, only epilimnetic and hypolimnetic data will be displayed, or epilimnetic data only if the lake is too shallow to form layers. Follow the trends within each layer and note any changes for each parameter.

Tributary: stream, inlet

Then examine the **tributary** data. Look at each inlet, one at a time. Some will reflect good conditions (low total phosphorus, low conductivity, and pH between 6.0 and 7.0). Others might reflect poor tributary quality, sending off a warning light (high total phosphorus, high conductivity, or low pH). List the possible problems you identified from your data and prioritize them according to your association's goals. Keep in mind that weather patterns during the sampling season will strongly affect the lake quality. Heavy rainfall or large amounts of snow melt can result in nutrient-rich and sediment-laden runoff to the lake. On the other hand, a dry season will have an absence of such runoff, potentially resulting in greater water clarity and less nutrients to feed algae and plant growth.

Weather patterns should be carefully considered when assessing lake changes from year to year, or even within a sampling season. Large variations in collected data may be observed from month to month when comparing a wet summer month to a dry month.

Biological: living plants or organisms

Chemical: parameters related to the chemistry of water

Physical: parameters that can be percepted using the senses, such as Secchi disk transparency

To provide an understanding of how your water body compares to other New Hampshire lakes the following table summarizes key **biological, chemical, and physical** parameters for all the state's lakes surveyed since 1976.

Summary Statistics for New Hampshire Lakes and Ponds (summer eplimnetic values)

Parameter	Number*	Min.	Max.	Mean	Median
pH (units)	806	4.3	9.3	**6.5	6.6
ANC (mg/L)	806	-3	85.9	6.7	4.8
Conductivity (uhmos/cm)	795	13.2	818	62.1	38.4
Turbidity (NTU)	272	<1	22	N/A	1.0
Total Phosphorus (ug/L)	799	<1	121	N/A	11
Chlorophyll-a (mg/m^3)	821	0.19	143.8	7.02	4.55
Secchi Disk (m)	830	0.40	13.0	3.7	3.2

* Number = the number of lakes sampled

** = true mean pH

N/A = Not applicable

Finally, refer to the Observations and Recommendations section of this report, which discusses the basic trend data and also lists some suggestions for future sampling. Then, formulate a plan and call us for help. Once you know where your concerns lie, we will work with you to modify your current sampling program to address these goals. You may also be eligible to be involved in the NH Clean Lakes Program (NHCLP) which provides more detailed watershed diagnostic tests and recommends Best Managment Programs to reduce pollutants to the lake. The NHCLP can lead to watershed management programs through the Local Initatives Grants offered by DES. Don't procrastinate too long; summer will be here before you know it!

Monitoring Parameters

Biological Parameters

Algal Abundance

Algae are photosynthetic plants that contain chlorophyll but do not have true roots, stems, or leaves (a.k.a. "phytoplankton"). They do, however, grow in many forms such as aggregates of cells (colonies), in strands (filaments), or as microscopic single cells.

Photosynthesis: producing carbohydrates with the aid of sunlight

Food chain: arrangement of organisms in a community according to the order of predation

Oxygenated: holding oxygen in solution

Regardless of their form, these primitive plants carry out **photosynthesis** and accomplish two very important roles in the process. First, inorganic material is converted to organic matter. These tiny plants then form the base of a lake **food chain**. Microscopic animals (zooplankton) graze upon algae like cows graze in a field. Fish also feed on the algae along with other organisms. Second, the water is **oxygenated**, aiding the chemical balance and biological health of the lake system.

Algae require light, nutrients, and certain temperatures to thrive. All of these factors are constantly changing in a lake from day to day, season to season, and year to year. Therefore, algae populations and the abundance of individual species of algae naturally fluctuate with weather changes or changes in lake quality.

Chlorophyll-a: a green pigment found in algae

Oligotrophic: low biological production

Eutrophic: high biological production; nutrient rich

Mean: average

NHVLAP uses the measure of **chlorophyll-a** as an indicator of the algae abundance. Because algae is a plant and contains the green pigment chlorophyll, the concentration of chlorophyll found in the water gives us an estimation of the concentration of algae. If the chlorophyll-a concentration increases, this indicates an increase in the algal population. Generally, a chlorophyll-a concentration of less than 4 mg/m^3 indicates water quality conditions that are representative of **oligotrophic** lakes, while a chlorophyll-a concentration greater than 15 mg/m^3 indicates **eutrophic** conditions. A chlorophyll concentration greater than 10 mg/m^3 generally indicate an algae bloom, or the excessive reproduction of algae.

The **mean** chlorophyll-a concentration for New Hampshire lakes is 7.02 mg/m^3. Figure 1 (App.A) and Table 1 (App.B) present the mean chlorophyll-a concentration for each year of participation in NHVLAP. Table 1 also presents the minimum and maximum values recorded for the same years.

Chlorophyll-a (µg/L)	
0-5	Good
5.1-15	More than desirable
>15	Nuisance amounts

Phytoplankton

Phytoplankton: microscopic algae floating in the water column

Plankton net: fine mesh net used to collect microscopic plants and animals

Periphyton: an assemblage of microorganisms (plants and animals) firmly attached to and growing upon solid surfaces such as the bottom of a lake or stream, rocks, logs, and structures.

Succession: the decline of dominant species of algae over a period of time as another species increases and becomes dominant

Blue-green algae: A group of phytoplankton which often cause nuisance conditions in water, so called because they contain a blue pigment in addition to chlorophyll. Blue-green algae are often associated with problem blooms in lakes. Some **(Cyanobacteria)** produce chemicals toxic to other organisms, including humans. They often form floating scum as they die. Many can use nitrogen (N_2) from the

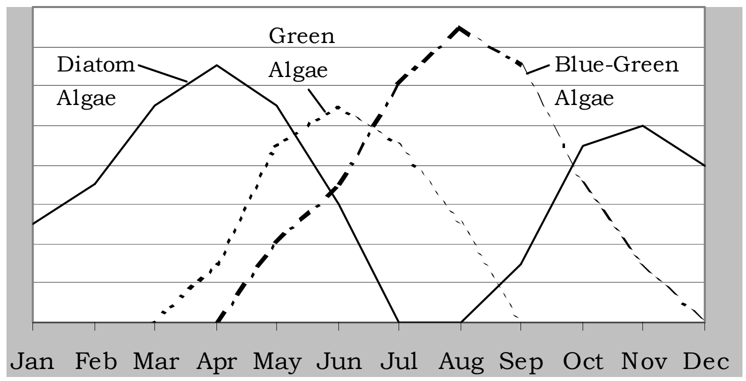
The type of **phytoplankton** present in a lake can be used as an indicator of general lake quality. The most direct way to obtain phytoplankton information involves collection of a sample with a **plankton net**, measurement of the quantity of phytoplankton contained in the sample, and identification of the species present using a microscope. An abundance of cyanobacteria (blue-green algae), such as *Anabaena, Aphanizomenon, Oscillatoria,* or *Microcystis* may indicate excessive phosphorus concentration or that the lake ecology is out of balance. On the other hand, diatoms such as *Asterionella, Melosira,* and *Tabellaria* or golden-brown algae such as *Dinobryon* or *Chrysosphaerella* are typical phytoplankton of New Hampshire's less productive lakes. In shallow warm waters with minimal wave action (such as a cove), filamentous green algae may grow in a form that looks like a mass of green cotton candy. **Periphyton** may grow on rocks or vegetation, causing these to be slippery.

Phytoplankton populations undergo a natural **succession** during the growing season. Many factors influence this succession: amount of light, availability of nutrients, temperature of the water, and the amount of grazing occurring from zooplankton. As shown in the diagram on page 10, it is natural for diatoms to be the dominant species in the spring and then green algae in the early summer, while **blue-green algae** may dominate in mid to late summer. The plankton samples from your lake will show different dominant species, depending on when the samples were taken. Phytoplankton are identified in Table 2 in Appendix B. Phytoplankton groups and species are listed below.

Phytoplankton Groups and Species for New Hampshire Lakes and Ponds

	Greens		
Actinastrum	*Eudorina*	*Pandorina*	*Spirogyra*
Arthrodesmus	*Kirchneriella*	*Pediastrum*	*Staurastrum*
Dictyosphaerium	*Micractinium*	*Scenedesmus*	*Stigeoclonium*
Elakotothrix	*Mougeotia*	*Sphaerocystis*	*Ulothrix*
	Diatoms		
Asterionella	*Melosira*	*Rhizosolenia*	*Synedra*
Cyclotella	*Pleurosigma*	*Surirella*	*Tabellaria*
Fragilaria			
	Dinoflagellates		
Ceratium	*Peridinium*	*Gymnodinium*	
	Blue-Greens		
Anabaena	*Chroococcus*	*Gloeotrichia*	*Microcystis*
Aphanizomenon	*Coelosphaerium*	*Lyngbya*	*Oscillatoria*
Aphanocapsa			
	Golden-Browns		
Chrysosphaerella	*Mallomonas*	*Synura*	*Uroglenopsis*
Dinobryon			

A Typical Seasonal Succession of Lake Algae



Cyanobacteria

Cyanobacteria: Bacterial microorganisms that photosynthesize and produce chemicals toxic to other organisms, including humans.

Zooplankton: Small, usually microscopic animals found in lakes and reservoirs that possess little or no means of propulsion. Consequently, animals belonging to this class drift along with the currents.

Cyanobacteria are bacterial microorganisms that photosynthesize. Many species of cyanobacteria may accumulate to form surface water “blooms”. They are blue-green in color and may consist of thousands of individual cells. Cyanobacteria are some of the earliest inhabitants of our waters, and they are naturally occurring in all of our lakes. However, research indicates that their abundance increases as the nutrients in a lake increase. They are part of the aquatic food web and can be eaten by various grazers in the lake ecosystem, such as **zooplankton** and mussels.

Although they are most often seen when floating near the surface, many cyanobacteria species spend a portion of their life cycle on the bottom of the lake during the winter months. As spring provides more light and warmer temperatures, cyanobacteria move up the water column and eventually rise toward the surface where they can form dense blooms or scums, often seen in mid to late summer and, weather permitting, sometimes well into the fall.

Some cyanobacteria produce toxins that adversely affect livestock, domestic animals, and humans. According to the World Health Organization (WHO), toxic cyanobacteria are found worldwide in both inland and coastal waters. The first reports of toxic cyanobacteria in New Hampshire occurred in the 1960 and 1970s. During the summer of 1999, several dogs died after ingesting toxic cyanobacteria from a blue-green algae bloom in Lake Champlain in Vermont. WHO has documented acute impacts to humans from cyanobacteria from the U.S. and around the world as far back as 1931. While most human health impacts have resulted from ingestion of contaminated drinking water, cases of illnesses have also been attributed to swimming in waters infested with cyanobacteria.

The possible effects of cyanobacteria on the "health" of New Hampshire lakes and their natural inhabitants, such as fish and other aquatic life, are under study at this time. The Center for Freshwater Biology (CFB) at the University of New Hampshire is currently examining the potential impacts of these toxins upon the lake food web. The potential human health hazards via exposure through drinking water and/or during recreational water activities are also a concern to the CFB and the state.

Neurotoxin: nerve toxins

Hepotoxins: liver toxins

Dermatoxins: toxins that cause skin irritations

Cyanobacteria occur in all lakes, everywhere. In New Hampshire, four of the most common cyanobacteria include: *Anabaena, Aphanizomenon, Oscillatoria, and Microcystis*. *Anabaena* and *Aphanizomenon* produce **neurotoxins** that interfere with the nerve function and have almost immediate effects when ingested. *Microcystis* and *Oscillatoria* are best known for producing **hepatotoxins** known as microcystins. *Oscillatoria* and *Lyngbya* (another blue-green algae) also produce **dermatotoxins**, which cause skin rashes.

Both DES and UNH have extensive lake monitoring programs. Generally, the water quality of New Hampshire's lakes is very good. However, the state strongly advises against using lake water for consumption, since neither in-home water treatment systems nor boiling the water will eliminate cyanobacteria toxins if they are present.

If you observe a well-established blue-green algae bloom or scum in the water, please comply with the following:

- Do not wade or swim in the water!
- Do not drink the water or let children drink the water!
- Do not let pets or livestock into the water!

Exposure to toxic cyanobacteria scums may cause various symptoms, including nausea, vomiting, diarrhea, mild fever, skin rashes, eye and nose irritations, and general malaise. If anyone comes in contact with a blue-green algae bloom or scum, they should rinse off with fresh water as soon as possible.

If you observe a blue-green algae bloom or scum, please call DES at 271-2304. DES will sample the scum and determine if it contains cyanobacteria that are associated with toxic production. An advisory will be posted on the immediate shoreline indicating that the area may not be suitable for swimming. DES will notify the town health officer, beach manager, and/or property owner, and the N.H. Department of Health and Human Services. DES will continue to monitor the water and will notify the appropriate parties regarding the results of the testing. When monitoring indicates that cyanobacteria are no longer present at levels that could harm humans or animals, the advisory will be removed.

Secchi Disk Transparency

Color: apparent water color caused by dissolved organic compounds and suspended materials

The Secchi disk is a 20 centimeter disk with alternating black and white quadrants. It has been used since the mid-1800s to measure the transparency of water. The Secchi disk is named after the Italian professor P.A. Secchi whose early studies established the experimental procedures for using the disk. The disk is used to measure the depth that a person can see into the water. Transparency, a measure of the water clarity, is affected by the amount of algae, **color**, and particulate matter within a lake. In addition, transparency reading may be affected by wave action, sunlight, and the eyesight of the volunteer monitor. Therefore, we recommend that 2 or 3 monitors take a Secchi disk reading, and then these readings should be averaged. In general, a transparency greater than 4 meters indicates oligotrophic conditions, while a transparency of less than 2 meters is indicative of eutrophic conditions.

The mean transparency for New Hampshire lakes is 3.7 meters (one meter equals 3 feet, 4 inches). Figure 2 in Appendix A presents a comparison of the transparency values for each of the VLAP monitoring years, while Table 3 of Appendix B shows minimum, maximum, and mean values for all years of participation.

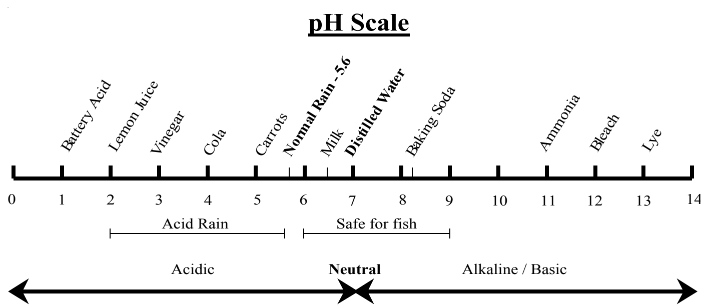
Water Clarity (Transparency) Ranges for Lakes and Ponds

Category	Water Clarity (m)
Poor	<2
Good	2-4.5
Exceptional	>4.5

Chemical Parameters

pH

pH is measured on a logarithmic scale of 0 to 14. The lower the pH the more acidic the solution, due to higher concentrations of hydrogen ions. Acid rain typically has a pH of 3.5 to 5.5 due to pollutants added from the air. In contrast, the median pH for New Hampshire lakes is 6.6.



Lake pH is important to the survival and reproduction of fish and other aquatic life. A pH below 5.5 severely limits the growth and reproduction of fish. A pH between 6.5 and 7.0 is ideal.

Many lakes exhibit lower pH values in the deeper waters than nearer the surface. This effect is greatest in the bottom waters of a **thermally stratified** lake. Decomposition carried out by **bacteria** in the lake bottom causes the pH to drop, while photosynthesis by **phytoplankton** in the upper layers can cause the pH to increase. Tannic and humic acids released to the water by decaying plants can create more acidic waters in areas influenced by wetlands. After the acidic spring-time snow melt or a significant rain event, surface waters may have a higher pH than deeper waters and may stake several weeks to recover.

Thermally stratified: water layered by temperature

Bacteria: tiny organisms that break down dead matter

Phytoplankton: microscopic algae floating in the water column

Table 4 in Appendix B presents the in-lake and tributary true mean pH data.

pH Ranges for New Hampshire Lakes and Ponds

Category	pH (units)
Acidified	<5
Critical	5.0-5.4
Endangered	5.5-6.0
Satisfactory	6.1-8.0

Acid Neutralizing Capacity

Buffering capacity or Acid Neutralizing Capacity (ANC) describes the ability of a solution to resist changes in pH by neutralizing the acidic input to the lake. The higher the ANC the greater the ability of the water to neutralize acids. This concept can be compared to a person taking an antacid, such as

TUMS to neutralize stomach acid indigestion. Low ANC lakes are not well buffered. These lakes are often adversely affected by acidic inputs.

Historically, New Hampshire has had naturally low ANC waters because of the prevalence of granite bedrock. (Granite does not contain elements that have buffering capacity, like limestone.) The average ANC for New Hampshire lakes is 6.7 mg/L. This relatively low value makes them vulnerable to the effects of acid precipitation. Table 5 in Appendix B presents the mean epilimnetic ANC for each year your association has been involved in this program.

Acid Neutralizing Capacity Ranges for New Hampshire Lakes and Ponds

Category	ANC (mg/L)
Acidified	<0
Critical	0-2
Endangered	2-5
Highly Sensitive	5-10
Sensitive	10-20
Not Sensitive	>20

Conductivity

Ionic paricle(s): an atom or group of atoms carrying an electrical charge

Conductivity is the numerical expression of the ability of water to carry an electrical current. It is determined primarily by the number of **ionic particles** present. The soft waters of New Hampshire have traditionally had low conductivity values. High conductivity may indicate pollution from such sources as road salting, faulty septic systems, or urban/agricultural runoff.

Erosion: soil materials worn away by the action of water or wind

Specific categories of good and bad levels cannot be constructed for conductivity, because variations in watershed geology can result in natural fluctuations in conductivity. However, values in New Hampshire lakes exceeding 100 generally indicate cultural (man-made) sources of ions. The conductivity should remain fairly constant for a given lake throughout the year. Any major changes over a short period of time may indicate **erosion** resulting from heavy rain or a large flush of runoff from a problem site. Conductivity less than 50 umhos/cm is typical of oligotrophic lakes. Conductivity greater than 100 umhos/cm is more typical of lakes with greater human impacts.

The mean conductivity for New Hampshire lakes is 62.1 umhos/cm. Table 6 in Appendix B presents mean conductivity values for tributaries and in-lake data.

Phosphorus

Algal blooms: over-population of algae

Phosphorus is the most important water quality parameter measured in our lakes. It is this nutrient that limits the algae's ability to grow and reproduce. Limiting phosphorus in a lake will result in lower or reduced, natural algae concentration. Increased phosphorus levels encourage excessive plant growth and **algal blooms.** Phosphorus occurs in many forms in a lake and is absorbed by algae, becoming part of a living cell. When the algae cell dies the phosphorus is still organically bound, even as the dead cells settle to the lake bottom.

Median: a value in an ordered set of values below and above which there is an equal number of values

Phosphorus sources around a lake include septic systems, animal waste, lawn fertilizer, road and construction erosion, and natural wetlands.

An in-lake epilimnetic phosphorus concentration of less than 10ug/L indicates oligotrophic conditions, while a concentration greater than 20 ug/L in the upper layer is indicative of eutrophic conditions. The **median** phosphorus concentration in the upper water layer of New Hampshire lakes is 11 ug/L. The **median** phosphorus concentration in the lower water layer is 14 ug/L.

Figure 3 in Appendix A shows the epilimnetic and hypolimnetic total phosphorus values for 2002 and historical data. Table 8 in Appendix B presents mean total phosphorus data for in-lake and tributary data.

Total Phosphorus Ranges for New Hampshire Lakes and Ponds (Epilimnetic)

Category	TP (ug/L)
Low (good)	1-10
Average	11-20
High	21-40
Excessive	>40

Dissolved Oxygen and Temperature

The presence of dissolved oxygen is vital to bottom-dwelling organisms as well as fish and amphibians. If the concentration of dissolved oxygen is low, species intolerant to this situation, such as trout, will be forced to move or may not survive.

Temperature is also a factor in the dissolved oxygen concentration. Water can hold more oxygen at colder temperatures than at warmer temperatures. Therefore, a lake will typically have a higher concentration of dissolved oxygen during the winter, spring, and fall than in summer.

At least once during this summer, a DES biologist measured dissolved oxygen and temperature at set intervals from the bottom of the lake to the surface.

Thermal stratification: water layering by temperature

ppm: parts per million; equal to mg/L

Internal loading: addition of phosphorus to the hypolimnion from the lake sediments due to low oxygen conditions

Thermocline: barrier between warm surface layer and cold deep layer where a rapid decrease in water temperature occurs with increasing depth

These measurements allow us to determine the extent of **thermal stratification** as well as the lake oxygen content. Many of the more productive lakes experience a drop in dissolved oxygen in the deeper waters as the summer progresses. Bacteria in the lake sediments decompose the dead organic matter that settles out, a process that depletes oxygen in the bottom waters. Since more productive lakes tend to have organic-rich sediments there will be greater decomposition on the bottom of such lakes, potentially creating a severe dissolved oxygen deficit (less than 1 **ppm**). This low oxygen condition can then trigger phosphorus that is normally bound to the sediment to be released into the water (**internal loading**).

Dissolved oxygen percent saturation shows the percentage of oxygen that is dissolved in the water at a particular depth. Typically, the deeper the reading the lower the percent saturation. A high reading at or slightly above the **thermocline** may be due to a layer of algae, producing oxygen during photosynthesis. Colder waters are able to hold more dissolved oxygen than warmer waters, and generally, the deeper the water the colder the temperature. As a result, a reading of 9 mg/L of oxygen at the surface will yield a higher percent saturation than a reading of 9 mg/L of oxygen at 25 meters, because of the difference in water temperture. Table 9 in Appendix B illustrates the Dissolved Oxygen/Temperture profile(s) for 2002, and Table 10 shows historical hypolimnetic dissolved oxygen readings.

<u>Turbidity</u>

Turbidity in water is caused by suspended matter, such as clay, silt, and algae that cause light to be scattered and absorbed, not transmittted in straight lines through the water. Secchi disk transparency, and therefore water clarity, is strongly influenced by turbidity. High turbidity readings are often found in water adjacent to construction sites; during rain events unstable soil erodes and causes turbid water downstream. Also, improper sampling techniques (hitting the bottom of the lake with the Kemmerer bottle or stirring up the stream bottom when collecting tributary samples) may also cause high turbidity readings. The New Hampshire median for lake turbidity is 1.0 NTU. Table 11 in Appendix B lists turbidity data for 2002.

Statistical Summary of Turbidity Values for New Hampshire Lakes and Ponds

Category	Value (NTU)
Minimum	<0.1
Maximum	22.0
Median	1.0

Bacteria

Surface waters contain a variety of microorganisms including bacteria, fungi, protozoa, and algae. Most of these occur naturally and have little or no impact on human health. Health risks associated with water contact occur generally when there is contamination from human sources. Warm blooded animals such as ducks, beaver, geese, and pets can also contribute bacteria to surface waters. Contamination arises most commonly from sources of fecal waste such as failing or poorly designed septic systems, leaky sewage pipes, nonpoint source runoff from wildlife habitat areas, or inputs from wastewater treatment plant outflows within a watershed. Swimming beaches with heavy use, shallow swim areas, and/or poor water circulation also have commonly reported bacteria problems. Therefore, water used for swimming should be monitored for indicators of possible fecal contamination. Contamination is typically short-lived, since most bacteria cannot survive long in cold water; their natural environment is the gut of warm blooded animals. A recent study has shown that E. coli can live fairly long periods of time in the sediments.

Specific types of bacteria, called indicators, are the basis of bacteriological monitoring, because their presence tends to indicate fecal contamination.

Indicators estimate the presence and quantity of things that cannot be meaured easily by themselves. We measure these sewage or fecal indicators rather than the **pathogens** themselves to estimate sewage or fecal contamination and, therefore, the possilbe risk of disease associated with using the water.

Pathogens: disease-causing organisms

New Hampshire closely follows thebacteria standards recommended by the US Environmental Protection Agency (EPA). Following a 1988 EPA report recommending the use of *E. coli* as a standard for public water supplies and human contact, NH followed suit by adopting *Escherichia coil* (*E. coli*) as the new indicator organism. The new standards for Class B waters specify that no more than 406 *E. coli*/100 mL, or a geometric mean based on at least 3 samples obtained over a 60 day period be greater than 126 *E. coli*/100 mL. Designated beach areas have more stringent standards: 88 *E. coli*/100 mL in any one sample, or a geometric mean of three samples over 60 days of 47 *E. coli*/100 mL. Table 12 shows bacteria (*E. coli*) results for 2002.